

# MODIS SCIENCE DATA SUPPORT TEAM PRESENTATION\*

June 14, 1991

## AGENDA

1. Action Items
2. MODIS-T Instrument Meeting
3. MODIS Airborne Simulator
4. Assumptions/Tracking List
5. Scenarios for Level-1 Processing

\*The MODIS Science Data Support Team (SDST)  
was formerly called the MODIS Data Study Team

## ACTION ITEMS:

05/03/91 [Tom Goff and Team]: Document plans for Level-1A and Level-1B processing, and indicate what information will be included in each product. Include a list of assumptions, brief rationale, scenarios, and trade-offs. A draft version is included in today's presentation. STATUS: Open. Due date 06/07/91

05/03/91 [Lloyd Carpenter]: Prepare a Level-1 processing assumptions, questions and issues list, to be distributed to the Science Team Members and the MCST for comment. A "final" version is included in today's presentation. STATUS: Open. Due date 06/07/91.

05/31/91 [Liam Gumley]: Talk with Mike King as soon as he returns about what he wants and what he needs from the SDST as far as MAS processing is concerned. A report is included in today's presentation. STATUS: Open. Due date 06/21/91

05/31/91 [Liam Gumley]: Talk to Chris Justice at GSFC to find out what the MAS requirements are from the land disciplines. STATUS: Closed. Due date 06/07/91

05/31/91 [Liam Gumley]: Investigate the status of existing WILDFIRE code with regard to the availability, size, complexity, documentation, and the ease with which it could be ported to a different environment. STATUS: Closed. Due date 06/07/91

05/31/91 [Al McKay and Phil Ardanuy]: Examine the effects of MODIS data product granule size on Level-1 processing, reprocessing, archival, distribution, etc. STATUS: Open. Due Date 06/21/91

## MODIS-T Instrument Meeting

Minutes of a meeting between SDST representatives, MCST representatives, and a MODIS-T instrument system engineering representative concerning MODIS-T Instrument issues as related to the MODIS Science Data Support Team processing design effort,

<u>Attendees</u>	<u>Affiliation</u>	<u>Function</u>
Lloyd Carpenter	RDC	SDST
Al McKay	RDC	SDST
Tom Goff	RDC	SDST
John Barker	code 925	MCST
Harold Geller	RDC	MCST
Mike Roberto	code 725.3	MODIS Instrument

### Meeting Materials

Spread Sheet printout of the MODIS-T Telemetry - 6/10/91

MEMO - "Data Packets for MODIS-T", from 725.3 to Distribution - October 1, 1990

### Data Packet Alignment with the Scan Cube.

The current telemetry list for MODIS-T has 13578 bits per frame. This allows two CCSDS packets to carry one telemetry frame and this appears to be the method to be followed. This allows the simplest design of the instrument Data Handling system and fits well with the proposed MODIS Level-1A processing design. In order to reassemble the scan cube in the Level-1A process, a proposal was made to include a packet counter within the telemetry (not the CCSDS header) that begins with one and increments to approximately 2048 (the number of packets in a scan cube). In addition, a recommendation to include a scan cube counter, reset to one at the change of orbit number (beginning of the night time pass) was presented.

### MODIS-T Tilting Determination.

MODIS-T is required to have a "stare" mode to allow the instrument to continuously view a given ground location while the satellite moves. This implies that the instrument will tilt for each scan cube of data. The Science Data Support Team has a concern that the instrument IFOV be stable during the detector integration to avoid a 'smearing' of data during tilt. This concern may be addressed by tilting the instrument only during the non-Earth portions of the scan. For a mirror rotation time of 6.6 rpm, a total scan time becomes 4.545 seconds (double sided mirror). The on-Earth time is slightly over a second leaving three plus seconds to change the tilt angle. Unofficial information has indicated that a 40 degree tilt can be accomplished and stabilized during this back scan interval. This capability is very dependent upon the instrument power budget which appears to be limited and may not allow this tilt rate to be accomplished. This item is under study by the instrument personnel.

The telemetry spread sheet indicates that a tilt encoder readout will occur at each frame (two packets) of data and can be used to determine the tilt stability in addition to calculating the scan anchor points.

### **Engineering Data.**

All data associated with the instrument will be contained within each scan cube. No data will be separated into components and scattered across scan cubes.

### **Instrument Commanding.**

There is no current means or mechanism for recording instrument commands in the MODIS telemetry packets. However, all status indicators will be included in the MODIS telemetry packets. The processing design has an assumption that instrument status can not be compared with telemetered values because the ICC log will not be available at processing time. This item is being investigated by the instrument personnel.

### **Instrument Pointing Accuracies.**

The current budget for the instrument pointing accuracies is 90 arc seconds. This is for the instrument only, not the spacecraft platform. This specification gives a 307 meter potential error for a satellite height of 705 Kilometers. This may not allow proper registration of MODIS-N cloud determination with MODIS-T data. The SDST has recommended that a spread sheet be disseminated that illustrates the accuracy budget within the instrument components that can possibly lead to further improvement.

### **MODIS Packet Application Process IDs.**

There is currently a recommendation from the instrument system engineering group that four MODIS packet IDs be available (normal, swath end, night data, and diagnostic). The MCST recommends adding one or more ID's to this list which would include Lunar mode calibration among other modes. These can be CCSDS Application Process IDs or possibly a special ID or packet subheader ID. Having separate IDs enables CDOS to discriminate Quick\_Look priority processing to allow 'bent pipe' (non time ordered) processing automatically.

### **Instrument Mode Switching.**

The SDST representatives recommended that a change of instrument mode occur only during the back scan portion of the mirror rotation.

### **Pixel Interleaving.**

The requirement that all bands of MODIS-T instrument data for a given pixel be located within a common packet was noted.

### **Questions for Future Consideration.**

How accurate is the 64 bit time clock reference? Which clock (instrument or spacecraft) is in the telemetry, and which is in the CCSDS header? In what form (i.e. BCD, milliseconds since launch) is this clock data? Is the clock data read in a serial or parallel mode?

What instrument information needs to be included as metadata in the MODIS processing chain?

If broadcasting is used, will this data be ingested into EOSDIS and if so, by the MODIS Level-1A processor or a companion program?

The SDST assumes that the GPS satellite positioning will be available. If not, how will satellite position and attitude be determined and how accurate will these values be?

ACTION ITEMS FROM SDST MEETING 06/07/91 [Liam Gumley]

(1) Talk to Mike King about his requirements for MAS processing.

I met with Mike King at GSFC and heard his views on how the MAS processing should proceed. He believed that the SDST should be involved in processing MAS data to a "Level-1B" stage, where the data would consist of calibrated and geolocated radiances. There is a Level-1A processing stage which is done at Ames. This involves the conversion of the ER-2 aircraft data (Level-0) to an intermediate format which contains digital instrument counts, black body thermistor counts, time, aircraft position etc.

Since the MAS will evolve with time, the Level-1B processing should accommodate changes such as

- varying total number of instrument channels (up to 50),
- varying number of digitization levels for each channel (8 to 12 bits),
- different spectral bands,
- different spectral bands assigned to different instrument channels.

In order to obtain more than 8 bits in a given channel, it may be necessary to use another channel as storage space for the extra bits. It is also important to note that changes to the MAS may make it possible for some of the cases mentioned above to change DURING a flight mission. For example, it may be possible to install two sets of 50 spectral channels on the MAS, and switch between them during flight.

It is important to be able to quickly review all the data for a given flight mission, and this could be done by a browse facility available after Level-1B processing. A browse dataset generated during Level-1B processing could consist of a reduced spatial resolution image of each straight line flight track in a mission, along with a composite image of all the flight lines. The primary purpose would be to identify clouds, and ocean/land features of interest. Several spectral bands, depending on the MAS configuration, would be used. The browse facility would be a local interactive GSFC facility, with the option of producing hardcopy images for users external to GSFC.

There should be several mechanisms by which end users could obtain the Level-1B data. Internet links are desirable, along with standard media such as 9 track magnetic tape or Exabyte tape. It is important to allow end users to perform further processing on external systems.

(2) Talk to Alfredo Huete and Alan Strahler about their requirements for MAS processing.

Have not yet been able to contact either. Efforts are continuing.

(3) Investigate browse generation.

I talked to Chris Moeller at Wisconsin to determine his strategy for MAMS browse/quicklook. When a set of data is received for a flight, it consists of every 3rd line to avoid along track oversampling. Every 15th line of this subsampled data set is examined to determine data dropout regions, cloud, land/ocean. A typical MAMS flight mission generates around 20000 to 25000 lines of good image data, which may be spread over 7 to 10 straight line flight tracks (see following processing summary for data rate information). Thus a typical flight track is 2000 to 3000 lines long. This would correspond to a typical "scene". It is useful to look at all spectral bands to determine if any problems occurred with the digitizer or associated electronics.

## MAS processing system summary (06/07/91)

The following is intended as a guide to current knowledge of the processing requirements for the MAS. It primarily deals with Level-1B processing, with the assumption that MAS data users will perform further processing on their own systems.

## MAS instrument details

Precursor	: Daedalus WILDFIRE sensor
Spectral bands	: 50
Output channels	: 12 8-bit channels initially (can configure 4 10-bit and 7 8-bit channels) and may increase to 50 12-bit channels eventually
IFOV	: 2.5 mrad initially, may change to 5.0 mrad
Flight altitude	: 20 kilometers (ER-2)
Ground resolution	: 50 meters at nadir for 2.5 mrad IFOV, 100 meters at nadir for 5.0 mrad IFOV
Total scan angle	: 85.92 degrees
Swath width	: 37 kilometers
Pixels per scan	: 716
Scan rate	: 6.25 scans per second (oversamples both cross track and along track)
Data rate	: 0.4296 megabits per second 193.32 megabytes per hour (for 12 8-bit channels)
Calibration	: Onboard blackbody targets for infrared bands. Pre and post flight ground-based integrating sphere for visible and near-infrared bands.

## MAS processing considerations

- The first WILDFIRE/MAS flight will occur in November 1991. The MAS processing system should be in place by this time.
- The aim of the MAS processing system should be produce Level-1B data with accurate calibration and navigation.
- Calibration accuracy is of primary importance to all users. Some users may wish to retain calibration source information in the 1-B product.
- Navigation accuracy desired varies between users, however accuracy better than half a pixel may be required. Users may need to perform their own ground control point navigation corrections to achieve these accuracies. Users may wish to use in-situ data in conjunction with MAS data so accurate navigation is essential.
- Some users may wish to perform geometric image corrections, so aircraft roll, pitch, yaw and altitude data should be preserved in the Level-1B dataset.

- Co-registration of the MAS spectral bands within a single pixel is of importance to some users. Whether this issue can be addressed in Level-1B processing remains to be determined.
- Accurate registration of images between flight tracks or flight missions is required by some users.
- MAS Level-1B processing will be performed at GSFC, on a platform to be decided. A possible option is a Silicon Graphics IRIS workstation. This would provide speed, imaging capability, and connectivity to other systems via Internet. Facilities must be available to ingest the Level-1A MAS data from the source format (9 track magnetic tape) and to distribute the 1-B product in the desired format for users.
- Processed Level-1B data should be readily available to users either by electronic network links or magnetic media. The exact format of these links and media remain to be determined.
- An interactive browse facility should exist to enable users to examine data from a flight in order to determine cloud cover and/or regions of interest. Users who are not able to access the browse facility interactively should be provided with equivalent hardcopy imagery.
- WILDFIRE/MAS data format is the same as exists for the MAMS. Code to process MAMS data has been developed at the University of Wisconsin-Madison under the direction of Paul Menzel. It may be desirable to utilize the PC-MCIDAS facility at GSFC Severe Storms Branch to help develop and validate the MAS processing system.
- Since the MAS will be an evolving system, with configuration changing from flight to flight, the MAS processing should be able to handle changes in instrument configuration. This may involve the number of channels, the number of bits per channel, the spectral band assigned to a given channel, changes in spectral bands during flight etc. These changes are as yet unclear in definition.

This list is subject to revision.

**MODIS TRACKING LIST**  
**Assumptions, Questions, and Tracking**  
**compiled by the**  
**MODIS Science Data Support Team**

**DRAFT**

**13 June 1991**

This master list of assumptions, tracking items and questions approaches a comprehensive list of all items associated with the design of the MODIS data processing. The intent is to clarify issues and prevent misunderstandings. Items that are assumptions have been included in the current MODIS processing design. They may be modified in future revisions as the design becomes further refined. Tracking items are included as reminders for other phases of the design. Questions for groups other than the MODIS Science Data Support Team are included with time tagged responses as received. This list is a living document that will change as needed.

Each item includes justification and trade-off information. Items that require a response from other groups will include dates for tracking purposes. The internal tracking number is included in parentheses in the title of each list item.

See the glossary at the end of this document for a definition of terms.

**MODIS and Scheduler Processing Interactions (049)**. The interface specifications between the MODIS processing programs and the SCA process are being investigated.

The MODIS process can be scheduled based on data availability or on the required generation of an output product. In either philosophy, tables of data availability must be kept by either the MODIS or the SCA process. The recommended contents of these tables and their driving forces are currently under investigation.

**MODIS Data (013)**. All non-duplicate Level-0 data packets with an Application Process ID that designates MODIS data will be retained in the MODIS Level-1A product.

Statistics containing duplicate packet, missing packet, and non-MODIS packet information will be included in the data product header and metadata. Quality assurance records, including but not limited to Moon looking, Sun looking, and other off-Earth looking indicators will also be included.

**Level-1A Data Product Granules (014)**. MODIS Level-1A data will be stored as data product granules including a granule header. Each product granule will consist of a whole number of complete scan cubes.

The output data product will not contain partial scan cubes. The data product granule pre-allocation scheme utilizes a scan cube as a quantum of data. This scan cube quantum of data is the smallest unit that may be individually addressed to form a deliverable data set. Problems associated with duplicate, partially filled scan cubes which may occur at the beginning and ending of Level-1A granules will be resolved in the Level-1B processing.

MODIS-T scan cube is expected to be about 1.8 MegaBytes in size while a MODIS-N scan cube is expected to be about 1.4 MegaBytes. There will be approximately 600 MODIS-T scan cubes per orbit and approximately 5000 MODIS-N scan cubes per orbit (day/night distribution). This gives an approximate orbital data product size of 1.1 GigaBytes for MODIS-T and 7.0 GigaBytes for MODIS-N.

**Level-1B Data Product Granules (029).** During Level-1B processing, the data contained in each MODIS Level-1A data product granule will be subdivided into Level-1B data product granules.

This assumption implies that a Level-1B data product granule is a subset of one and only one Level-1A data product granule. This assumption specifically excludes the concept of a database storage granule which is a different concept than the product granule.

If more than one Level-1A granule is needed to produce a required Level-1B granule, this can be accomplished by executing the MODIS Level-1B process twice, once for each input data product granule. The MODIS processing design, utilizing a previously derived output product granule with missing data, will fill in the missing portions from the current processing output. This capability is similar to the reprocessing mode also implemented in the current design philosophy.

**Granule Pre-Allocation (028).** The operating system is assumed to provide the capability of preallocating output product storage for all MODIS processing levels before input data is processed.

The operating system will provide a facility under which a process can request both memory and disk space. This space will be preallocated to a process before the actual processing of data begins. If the space is not available, the MODIS process must be rescheduled at a later time when the resources are available. The size of the preallocated spaces is determined by the MODIS process at execution time and is derived from the size of the input data product.

Defining the sizes and locations of the output product for each execution of the MODIS process allows the MODIS product to be fully generated without any premature aborting of the process. This also simplifies the accounting and correlation of input versus output data products by the scheduler.

The pre-allocated areas are filled with invalid data indicators which are used by further processes in the chain for quality assurance assessment and reprocessing scenarios.

**Level-0 Data Unpacking (016).** MODIS data will not be unpacked (byte aligned) at Level-1A.

Leaving the data in a packed form minimizes the size of the data set in the absence of data compression. It also minimizes the time and complexity of Level-1A processing. Unpacking the data at Level-1A may increase the probability of error in the lowest level of permanently archived data.

**Level-0 Data Packet Boundaries (015).** A MODIS Level-0 instrument data packet will not contain data from more than one scan cube.

This assumption implies that the scan cube boundaries will fall on instrument packet boundaries. A packet of MODIS data will not be scattered across two or more scan cubes. There is no constraint on the relationship between frame boundaries and instrument packet boundaries.

A question has been directed to the MODIS-T instrument systems engineering section via the MODIS Characterization Support Team (MCST) containing a request to clarify the subdivision of a scan cube into frames and packets. A preliminary answer indicated that two CCSDS packets of data can contain one instrument frame of data and therefore gives a desirable boundary for the packets that coincides with the most desirable boundaries from a processing viewpoint. Note that the specifications for the MODIS-N and -T instruments specify "band interleaved by line" and "pixel interleaved by band" formats respectively for the two instruments. The pixel interleaved by band format is desirable from a science view point to minimize the effect upon a multi-band algorithm due to a missing data packet.

The above same question will directed toward the MODIS-N instrument system engineering section following contract award for this instrument.

**Instrument Status Comparison (018).** MODIS Level-1A processing will not check instrument mode states or status contained in the Level-0 data against the Instrument Status Information maintained by the ICC.

The ICC command status log will not be available at the time of Level-1A processing. Therefore, it can not be performed without changing the current ICC plans.

If ICC commanding could be checked against telemetered commands and telemetered status, some problems could be detected in a more timely manner at an earlier stage in the processing chain.

**Instrument Status Comparison (045).** The MODIS Level-1B processing will not check instrument states against the Instrument Status Information issued by the ICC.

The ICC log will not be available for examination until 48 hours after items have been posted to the log. This time constraint does not allow the MODIS process to compare telemetered data with commanded states. Problems or anomalies detected in the telemetered data stream will be posted to the MODIS data product log and made available to other functions as necessary.

**Calibration (043).** Calibration algorithms and parameter values will be provided by the MCST.

Both algorithms and parameters (coefficients) will be incorporated into the Level-1B software by the SDST. Any change of algorithms or parameters will force a Configuration Management revision update. A full validation will be performed to detect overflow, underflow, error trapping, variable availability, etc.

**Navigating Data (017).** Earth locations of MODIS pixels will not be determined at Level-1A.

This function is contained in the Level-1B process.

**Instrument Position and Attitude Appending (050).**

The instrument platform ancillary (platform ephemeris) data is included as part of the Level-1A data product. However, it could also be provided to the Level-1B process by an external entity rather than being embedded in the Level-1A product. This would lower the possibility of multiple versions of this spacecraft data that could then lead to a lack of concurrency.

As an additional point, this information is also expected to be used by other processes besides the MODIS processes. This information is also asynchronous in time to any instrument scan times and therefore must be interpolated to a process requested time. The position and attitude are contained in data packets with a spacecraft unique Application Process ID and may not be available or tracked by the DADS in coincidence with the MODIS (or other) data packets.

**Platform Position and Attitude Knowledge (037).** MODIS Level-1B processing will use the satellite, at instrument, position and attitude knowledge supplied by the EOS project and appended to the Level-1A data.

This assumption implies that the MODIS process will not be executed before the instrument position and attitude are known. If the instrument or spacecraft position and attitude are updated after the MODIS data product has been generated, a MODIS reprocessing may have to be initiated by an outside authority. The current MODIS design appends the instrument position and attitude to the Level-1A data product. This can lead to a lack of concurrence (more than one version of a data set) with the attendant danger of not having the current, most accurate data.

For the Quick-Look mode, the best available position and attitude will be used with appropriate quality indicators. This may consist of data derived from orbital predicts or other similar methods.

**Required Ancillary Data (042).** All information required for MODIS Level-1B processing will be included in the MODIS Level-1A product.

The data product is defined to include its associated metadata. This assumption says that all data required to process to the Level-1B product (including metadata) will be contained within the Level-1A data product. This means that no in-situ data is required, and that no auxiliary data sets are required (i.e. other instrument motions causing momentum effects, platform thermal deformation data not in the MODIS packets, previous MODIS data products, etc.). See also: Engineering Data.

**Orbit and Attitude Correction (022).** The process of updating instrument position and attitude information already appended to Level-1A data will be performed by a separate utility process.

The current design of the MODIS processor simply appends the spacecraft platform position and attitude data to the Level-1A data product. Thus a utility program can 'patch' the platform data with newer or more correct values without reprocessing the Level-1A instrument data. The data product must contain the version number of the platform position and attitude data in addition to the processing version number to provide a means of checking for inconsistencies. Products based upon a given Level-1A product that has been updated might need to be reprocessed and would require a backwards pointer to the data source with the appropriate database links.

**Anchor Point Coordinate System (031).** Earth coordinates will be represented in the geodetic latitude-longitude coordinate system on a standard ellipsoid.

Coordinate transformations from the EOS platform coordinate system to the ground based geodetic latitude-longitude coordinate system will be performed by the MODIS processor using standardized transformation routines. Latitude will be given in the geodetic coordinate system. Longitude is identical in either the geodetic or geocentric system.

**Anchor Point Selection (032).** Within each scan cube, a set of anchor points will be selected for interpolating the ground locations of the pixels within the scan cube.

A non-linear set of approximately 150 anchor points per scan cube (3 along track, 51 across track) yields acceptable pixel positioning using a linear and cubic spline interpolation. See the report "An Analysis of MODIS Anchor Point Accuracies for Earth Location", MODIS Data Study Team, Revised: April 5, 1991 for details of the anchor point method accuracies. The ground locations of the selected pixels are determined solely from the satellite position, attitude, and instrument geometry without the use of ground (in-situ) control points.

**Anchor Point Parameters (033)**. The following parameters will be provided in the Level-1B data set for each anchor point: earth location (geodetic latitude-longitude) of the pixel, satellite slant range, satellite azimuth and zenith angles, and solar azimuth and zenith angles (all with respect to the pixel).

The zenith angles are relative to the normal to the local geodetic surface at the pixel. Other needed parameters such as solar to spacecraft relative azimuth can easily be calculated from the appended parameters. The slant range facilitates the computation of any digital elevation model (DEM) corrections in later processes.

**Anchor Point Error Statistics (034)**. No measure of earth pixel location accuracies will be included in the Level-1B data product.

These statistics can not be determined on a production basis. However, an indication of anchor point statistical angular variances can be derived externally in a non time critical environment by an auxiliary program. These angular accuracies are not unique to an individual data product. Pointing angles are to be derived from platform measurements initially and verified via off-line methods to be available after the MODIS data has been disseminated.

**Level-1B Feature Identification (035)** No Feature Identification or Ground Control Points will be used for Level-1B earth location.

No in-situ data, derived either from ground feature selection or a-priori positioning, will be required to geolocate the Level-1B data product.

**Level-1B Elevation Correction (036)**. There will be no terrain elevation correction (beyond the reference ellipsoid) to earth location anchor points during Level-1B processing.

Any use of a Digital Elevation Model (DEM) will be performed in follow-on processing upon the determination of a DEM procedure and appropriate model.

**Atmospheric Correction (038)**. No atmospheric correction of any kind will be applied to the MODIS level-1B data.

The definition of MODIS Level-1B data is at-satellite radiances, uncorrected for atmospheric effects such as absorptive, scattering, and refraction.

**Engineering Data (044)**. MODIS Level-1B processing will extract instrument engineering values from each Level-1A scan cube individually.

All of the instrument engineering values needed for calibration or other purposes, will be included in the Level-1A data product. No external data source will be required. All values required to perform a calibration of pixels within a scan cube will be contained within that same scan cube. Previous or future scan cube data will not be required to calibrate the current scan cube. If calibration requires a differing approach, the current design will require modification.

**Level-1A Land/Ocean Flags (024).** Land/Ocean flags, Cloud flags, or other derived information will not be included in the Level-1A data product.

The scan data is in uncalibrated digital (raw) count form thereby precluding the use of any cloud detection algorithm at Level-1A.

**Level-1B Land/Ocean Flags (039).** Land/Ocean flags will not be included in the Level-1B data product.

The current Level-1B design contains no provision for data flags of any kind. Generating a land/ocean flag would require a Team Member agreed upon coast line database and can be added to the current processor design.

**Level-1B Cloud Flags (051).** Cloud flags will not be included in the Level-1B data product.

Cloud flag determination would require a definitive cloud detection algorithm or means for a multi-valued flag. Cloud algorithms are expected to be derived from MODIS-N data and possibly applied to MODIS-T data. This would require registration of the two MODIS products during the Level-1B product generation.

**Level-1A Browse (026).** There will be no Level-1A browse product.

Browse data derived from raw instrument counts with no earth referencing would be of very limited use. Browse data requirements will be generated by the MODIS Science Team Members.

**Level-1B Browse (041).** The Level-1B process will not generate browse products.

Any required browse products will be generated by a separate browse process in order to take advantage of future technology advances without compromising the main data product processing. This allows technologies such as those currently in development for high definition television (HDTV), windowed graphical user interface (GUI), laser based video, or similar approaches to be used as they are developed without changing the basic Level-1B product generation function. This also allows for the concept of 'on the fly' or demand browse to be implemented.

**Data Compression (027).** No data compression will be performed within any of the MODIS processing levels.

Data compression, if implemented, is assumed to be performed in a process (hardware or software) that is external to any MODIS processing. This process is assumed to be a transparent, non delaying step, during the electronic transmission of data to/from storage. Software equivalents to hardware data compression techniques can be provided if necessary.

**Metadata Appending (030).** Each processing level updates and appends new metadata without deleting previous processing metadata information.

The metadata associated with an input product is updated to reflect further derived information. Previous metadata items are retained to allow backward tracking of information to the original source. This can be used for debugging and quality assurance determination. For example: The CDOS Reed-Solomon error statistics can be maintained with the mapped Level-3 product as an indication of the quality of that product. Metadata derived in the beginning of the processing chain will provide information which is useful for the generation of products later in that chain.

**Level-1A Land/Ocean Product Separation (025).** The Level-1A product will be supplied without separation into land/ocean or other categories.

Navigation is not performed in the Level-1A process. Therefore, earth referencing information is not available to allow a land/ocean flag to be generated.

**Level-1B Land/Ocean Product Separation (040).** The Level-1B product will be supplied without separation into land/ocean or other categories.

Level-1B MODIS data products are not categorized by spatial parameters when transferred to the archive although the headers and metadata contain statistics and indicators for this characterization. Data product splitting is a DADS function.

**Level-1A Reversibility (020).** Level-1A processing will be reversible to packets of Level-0 data.

The Level-1A data product, not the Level-0 data packets, will be permanently archived. Therefore, no non-redundant data will be deleted from the Level-0 packets in producing the Level-1A data product.

**Reversing Software (021).** A separate software package will be provided to reverse Level-1A data to Level-0 data packets.

The separation of the forward and reversing processes allows one program to be modified or updated without disturbing the integrity of the other. This also decreases the size and complexity of these programs, but adds an additional program to the full validation and configuration management responsibility. Duplicate data packets and non-MODIS packets will not be regenerated.

The separate programs to perform Level-1A processing, to reverse Level-1A to Level-0, and to compare the original Level-0 packets with the reconstructed Level-0 packets, should optimally be written by independent parties to verify documentation of the data formats and eliminate any errors in the processing.

**Processing Log (023).** A Processing Log, common to all MODIS processing programs, will be maintained consisting of a time ordered list of all MODIS processing events.

This Processing Log will receive messages in time order from all MODIS processing programs (Level-1A, Level-1B, Level-2, etc.). This allows an audit trail of MODIS problems and events that can be used as quality assurance inputs to other groups. The task of handling the MODIS Processing Log is performed by an external entity that is common to all MODIS processes.

**Quick-Look Data Product (019).** All Levels of Quick-Look data will be generated using the identical software as is used for the standard data product (assuming a time locality to the packet delivery in the case of the Level-1A product).

This design constraint assures that the revision level of any quick-look product matches that of the standard product and that only one piece of software is maintained. This satisfies the requirement of concurrency - only one definitive copy of a process. (See the discussion of the quick-look product in the Scenarios section of this document.)

The Level-1A processor is designed to accept data packets which are not in time order, provided that the packet sequence has reasonable time locality - the delivery of packet sequences is almost time ordered.

**046. Level-1B Quick-Look.** Level-1B Quick-Look data will be generated using the same version of software as is used for the standard Level-1B product.

(See the description under the Level-1A Quick\_Look item for a discussion of concurrency.)

## GLOSSARY

**Accuracy versus Knowledge** - Pointing accuracy is determined directly from measurements contained within the telemetry. Pointing knowledge are accuracy measurements that have been corrected using non-measured means (derived platform precession or ground control point correction for example). Knowledge is obtained from characterization studies.

**Application Process ID** - A unique number in the packet header used to direct all packets with this ID to a given destination. This number is assigned by the CCSDS.

**Scan Cube** - All the instrument data that is derived or measured during one swath (half of a mirror rotation) of the instrument. The cube consists of three parts: science data, engineering data, and auxiliary data. The science data occurs as a spatial cube with an across track pixel count (1007 for MODIS-T, 1354+ for MODIS-N), an along track pixel count (30 lines for MODIS-T, 8+ for MODIS-N), and a number of bands in depth (32+2 for MODIS-T, 36 for MODIS-N). For each data frame, auxiliary data is appended, consisting of tilt and mirror encoder angular position and time tag. Engineering data constitutes the voltage, current, relay positions, thermistor data, etc.

**Data Frame** - Data from the detector array, clocked out simultaneously. This consists of the along track pixels within a scan swath for all bands (wave lengths or frequencies).

**Granule** - the smallest unit of data to be handled by a specified entity. The use of the term "granule" is used in the context of the discussion. For example: a data product granule is the smallest unit of a data product that is of use to a user of that granule. A computer storage granule can be a scan cube of data if that is the smallest addressable unit. Granule should always be prefaced with an adjective specifying the context in which the term is used.

**Metadata** - Auxiliary data, associated with a data set or product, that contains information describing the contents of that data set or product. The metadata can be used to derive indices in a database, or as selection criteria in place of the actual data set or product.

## MODIS Level-1 Processing Assumptions

compiled by the  
MODIS Science Data Support Team  
13 June, 1991

This list of assumptions is associated with the design of the MODIS Level-1 data processing. The assumptions may change as comments are received, and as refinements are made to the Level-1 processing system design. The numbering of items comes from a master list being tracked by the MODIS Science Data Support Team. Only those items which may be of interest to MODIS Science Team members are included in this abbreviated list.

Unpacking Data (016). MODIS data will not be unpacked (byte aligned) at Level-1A.

Leaving the data in a packed form minimizes the size of the data set in the absence of data compression. It also minimizes the time and complexity of Level-1A processing. Unpacking the data at Level-1A could increase the probability of error in the lowest level of permanently archived data.

Navigating Data (017). Earth locations of MODIS pixels will not be determined at Level-1A.

This function is contained in the Level-1B process.

Required Ancillary Data (042). All information required for MODIS Level-1B processing will be included in the MODIS Level-1A product.

The data product is defined to include its associated metadata. This assumption says that all data required to process to the Level-1B product (including metadata) will be contained within the Level-1A data product. This means that no in-situ data is required, and that no auxiliary data sets are required (i.e. other instrument motions causing momentum effects, platform thermal deformation data not in the MODIS packets, previous MODIS data products, etc.). See also: Engineering Data.

Platform Position and Attitude Knowledge (037). MODIS Level-1B processing will use the satellite position and attitude knowledge supplied by the EOS project and appended to the Level-1A data.

This assumption implies that the MODIS process will not be executed before the spacecraft position and attitude are known and that if the spacecraft position or attitude are updated after the MODIS data product has been generated, a MODIS reprocessing may have to be initiated by an outside authority. The current MODIS design appends the satellite position and attitude to the Level-1A data

product. This can lead to a lack of concurrence (more than one version of a data set) with the attendant danger of not having the current, most accurate data.

For the Quick-Look mode, the best available position and attitude will be used with appropriate quality indicators. This may consist of data derived from orbital predictions or other similar methods.

**Orbit and Attitude Correction (022).** The process of replacing orbit and attitude information already appended to Level-1A data will be done in a separate utility process.

The current design of the MODIS process simply appends the spacecraft platform position and attitude data to the Level-1A data product. Thus a utility program can 'patch' the platform data with newer or more correct values without reprocessing the Level-1A instrument data. The data product must contain the version number of the platform position and attitude data in addition to the processing version number to provide a means of checking for inconsistencies. Products based upon a given Level-1A product that has been updated might need to be reprocessed and would require a backwards pointer to the data source with the appropriate database links.

Note that the spacecraft data could also be provided to the Level-1B process by an external entity rather than having it appended to the Level-1A product. The possibility of multiple versions of this spacecraft data can lead to a lack of concurrence and the resulting lack of consistent results.

This information is also expected to be used by other processes in addition to the MODIS processes. It is also asynchronous in time to any instrument scan times and therefore must be interpolated to a process requested time. The position and attitude are contained in data packets with a spacecraft unique Application Process ID and may not be available or tracked in coincidence with the MODIS (or other) data packets by the DADS.

**Coordinate System (031).** Coordinates will be represented in the geodetic latitude-longitude coordinate system on a standard ellipsoid.

Coordinate transformations from the EOS platform coordinate system to the ground based geodetic latitude-longitude coordinate system will be performed by the MODIS process using standardized transformation routines. Latitude will be given in the geodetic coordinate system.

**Anchor Points (032).** For each scan, a set of anchor points will be selected for interpolating the ground locations of pixels within the scan.

See the report "An Analysis of MODIS Anchor Point Accuracies for

Earth Location", MODIS Data Study Team, Revised: April 5, 1991 for details of the anchor point method. The ground locations of the selected pixels are determined solely from the satellite position, attitude, and instrument geometry without the use of ground (in-situ) control points.

**Anchor Point Parameters (033)**. The following parameters will be provided in the Level-1B data set for each anchor point: earth location (geodetic latitude-longitude) of the pixel, satellite slant range, satellite azimuth and zenith angles, and solar azimuth and zenith angles (all with respect to the pixel).

The zenith angles are relative to the normal to the local geodetic surface at the pixel. Other needed parameters such as solar to spacecraft relative azimuth can easily be calculated from the appended parameters. The slant range facilitates the computation of any digital elevation model (DEM) corrections in later processes.

**Anchor Point Error Statistics (034)**. No measure of earth location accuracies will be included in the Level-1B data product.

An indication of anchor point statistical accuracies can be derived externally in a non time critical environment. The accuracies are not unique to an individual data product. Accuracies are to be derived from platform knowledge parameters initially and verified via off-line methods to be available after the MODIS data has been disseminated.

**Feature Identification (035)**. No Feature Identification/Ground Control Points will be used at Level-1B for earth location.

No in-situ data, derived either from ground feature selection or a-priori positioning, will be required to produce the Level-1B data product.

**Land/Ocean Flags at Level-1A (024)**. Land/Ocean, Cloud, or other derived flags will not be included in the Level-1A data product.

The scan data is in uncalibrated digital (raw) count form thereby precluding the use of any cloud detection algorithm at Level-1A.

**Land/Ocean Level-1A Products (025)**. The Level-1A product will be supplied without separation into land/ocean or other categories.

Navigation is not performed in the Level-1A process. Therefore, earth referencing information is not available to allow a land/ocean flag to be generated.

**Land/Ocean Flags at Level-1B (039)**. Land/Ocean, Cloud, or other derived flags will not be included in the Level-1B data product.

The current Level-1B design contains no provision for data flags. Generating a land/ocean flag would require a Team Member agreed upon coast line database. A cloud flag would require a definitive cloud detection algorithm or means for a multi-valued flag.

**Level-1B Cloud Flags.** Cloud flags will not be included in the Level-1B data product.

Cloud flag determination would require a definitive cloud detection algorithm or means for a multi-valued flag. Cloud algorithms are expected to be derived from MODIS-N data and possibly applied to MODIS-T data. This would require registration of the two MODIS products during the Level-1B product generation.

**Land/Ocean Level-1B Products (040).** The Level-1B product will be supplied without separation into land/ocean or other categories.

Level-1B MODIS data products are not categorized by spatial parameters when transferred to the archive although the headers and Metadata contain statistics and indicators for this characterization. Data product splitting is a DADS function.

**Level-1B Elevation Correction (036).** There will be no terrain elevation correction (beyond the reference ellipsoid) to earth location at Level-1B.

Any use of a Digital Elevation Model (DEM) will be performed in follow-on processing upon the determination of a DEM procedure and appropriate model.

**Atmospheric Correction (038).** No atmospheric correction of any kind will be applied to the MODIS level-1B data.

The definition of MODIS Level-1B data is at-satellite radiances, uncorrected for atmospheric effects such as absorptive, scattering, and refractive effects.

**Level-1A Browse (026).** There will be no Level-1A browse product.

Browse data derived from raw instrument counts with no earth referencing would be of very limited use. Browse data requirements will be generated by the MODIS Science Team Members.

**Level-1B Browse (041).** The Level-1B process will not generate browse products.

Any required browse products will be generated by a separate browse process in order to take advantage of future technology advances without compromising the main data product processing. This allows technologies such as those currently in development for high definition television (HDTV), windowed graphical user interface (GUI), laser based video, or similar approaches to be used as they are developed without changing the basic Level-1B product generation function. This also allows for the concept of 'on the fly' or demand browse to be implemented.

**Calibration (043).** Calibration algorithms and parameter values will be provided by the MCST.

Both algorithms and parameters (coefficients) will be incorporated into the Level-1B software by the SDST. Any change of algorithms or parameters will force a Configuration Management revision update. A full validation will be performed to detect overflow, underflow, error trapping, variable availability, etc.

**Engineering Data (044).** MODIS Level-1B processing will extract instrument engineering values for calibration from each individual scan cube in the Level-1A data only.

All of the instrument engineering values needed for calibration will be included in Level-1A. No external data source will be required. All values required to perform a calibration of pixels within a scan cube will be contained within that same scan cube. Previous or future scan cube data will not be required to calibrate the current scan cube. If calibration requires a differing approach, the current design will require modification.

#### **QUESTIONS AND ISSUES:**

**Cloud/No-Cloud (009).** At which processing level will the cloud/no-cloud flag come into the system? Who determines if a cloud flag is desirable? Which algorithm is used to determine the presence of a cloud? Is it derived only from MODIS data or some other instrument that must be spatially co-located with MODIS?

**Quality Checks (010).** Who will provide a list of quality checks to be applied in the Level-1A and Level-1B processing? This includes product quality assurance (missing data, temporal characteristics, etc) and data quality (coherent noise, saturation, etc).

## Scenarios for the MODIS Level-1A and Level-1B Processing

13 June 1991

1. **Normal Processing:**                    { See June 7, 1991 handout }
2. **Quick-Look Processing:**                    { See June 7, 1991 handout }
3. **Metadata Generation:**

MODIS metadata consists of information describing the MODIS data which is obtained or derived from the data sets, and which provides an understanding of the content or utility of the data set. Metadata may be used to select and evaluate data for a particular scientific investigation.

Beginning at Level-0, each successive processing level will generate and append metadata as part of the data product. The metadata associated with the input product are updated to reflect further derived information. Previous metadata items are retained to allow backward tracking of information to the original source. This information can be used for debugging and quality assurance determination. For example, the CDOS Reed-Solomon error statistics can be maintained with the mapped Level-3 product as an indication of the quality of the original data that went into the product. Metadata derived in the beginning of the processing chain will provide information which is useful for the generation and assessment of products later in that chain.

Care must be taken in the interpretation of metadata in some cases. For example, error statistics for a granule of Level-1A data could be misleading when each Level-1A granule is subdivided into several granules at Level-1B. Some of the Level-1A statistical information may not be correct when applied to the subset of data which went into a particular Level-1B granule, etc. The reverse situation occurs, for example, when many Level-2 granules are used as input to a Level-3 process which generates an average value and a secular rate of change for some parameter. However, with a complete trail of metadata information, the user should be able to trace the heritage of his data and properly interpret his results.

4. **Browse Data Generation:**                    { See June 7, 1991 handout }
5. **Processing Previously Missing Data:**
6. **Reprocessing:**
  - A. **New Version of Software:**
  - B. **New Version of Ancillary Data:**